CHAPTER V

NUMERICAL RESULTS

In previous chapter the diffusivity-mobility ratio for n-type heavily doped semiconductors was obtained. In this chapter we will use this result to evaluate it numerically by the method given in section 4.3.2. A particular attention is given to considering the behavior of the diffusivity-mobility ratio at temperature T and with compensation ratio N_a/N_d as adjustable parameters and comparing our numerical results with the numerical results obtained using the empirical diffusivity-mobility ratio (3.20).

5.1 Numerical results

The numerical results of diffusivity-mobility ratio of n-type GaAs calculated by using the diffusivity-mobility ratio for n-type heavily doped semiconductors (4.68) and the empirical diffusivity-mobility ratio (3.20) with compensation ratio $N_a/N_d = 0.0$ at temperatures $T = 10K$, 77K and 300K, are shown in Table 1, 2, 3 and Figure 4, 5, 6 respectively against the net carrier concentration $N_d - N_a$.

The value of diffusivity-mobility ratio obtained by (4.68) lies above those obtained using the empirical diffusivity-mobility ratio and the difference between them is smaller when the temperature increases. However, the difference between their numerical values shown in Tables 1, 2 and 3 are small. This shows little dependence of the diffusivity-mobility ratio on the band tail density of states. For a net carrier concentration over 10^{19} cm^{-3} the empirical diffusivity-mobility ratio (3.20)

$$\frac{D}{\mu} \cong V_T\, u \left\{ \frac{V'(u)W(u) - V(u)W'(u)}{W^2(u)} \right\}$$

can be used by ignoring entirely the band tail density of states.

The dashed lines in Figure 4, 5, 6, 7, 8 and 9 show the minimum net carrier concentration at which the present Thomas-Fermi screening approximation is valid only for (4.36)

$$\xi_Q^{1/2} \leq E_f - E_C .$$

Hence, the present results (D/μ) are valid only for right hand side of the dashed lines. This requires net carrier concentrations to be large enough that the electrons are always degenerate in the region where the present model is valid.

$N_d - N_a$ (cm^{-3})	Q ($x10^6\ cm^{-1}$)	$\xi_Q^{1/2}$ (meV)	$E_f - E_C$ (meV)	D/μ ($x10^{-5}V$)	D/μ_0 ($x10^{-5}V$)	%diff
$1.000x10^{16}$	0.7152	0.3686	0.06665	0.9054	0.6079	-32.9
$5.000x10^{16}$	1.068	5.785	5.115	1.956	1.536	-21.5
$6.471x10^{16}$	1.132	6.393	6.393	2.251	1.817	-19.3
$7.000x10^{16}$	1.153	6.590	6.828	2.351	1.913	-18.6
$8.000x10^{16}$	1.187	6.942	7.909	2.533	2.089	-17.5
$9.000x10^{16}$	1.218	7.270	8.380	2.707	2.257	-16.6
$1.000x10^{17}$	1.246	7.576	9.112	2.874	2.419	-16.2
$5.000x10^{17}$	1.721	14.41	29.82	7.538	7.042	-6.58
$1.000x10^{18}$	1.956	19.12	48.31	11.68	11.17	-4.32
$5.000x10^{18}$	2.593	37.13	144.6	33.23	32.67	-1.70
$1.000x10^{19}$	2.917	49.52	230.7	52.47	51.85	-1.18
$5.000x10^{19}$	3.828	96.64	678.9	152.4	151.6	-0.51
$1.000x10^{20}$	4.301	128.9	1079	241.6	240.7	-0.36
$5.000x10^{20}$	5.629	252.0	3162	704.9	703.8	-0.16
$1.000x10^{21}$	6.317	336.4	5009	1120	1117	-0.24
$5.000x10^{21}$	8.268	657.4	$1.468x10^4$	3270	3267	-0.09

Table 1 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.0$ and temperature $T = 10K$

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

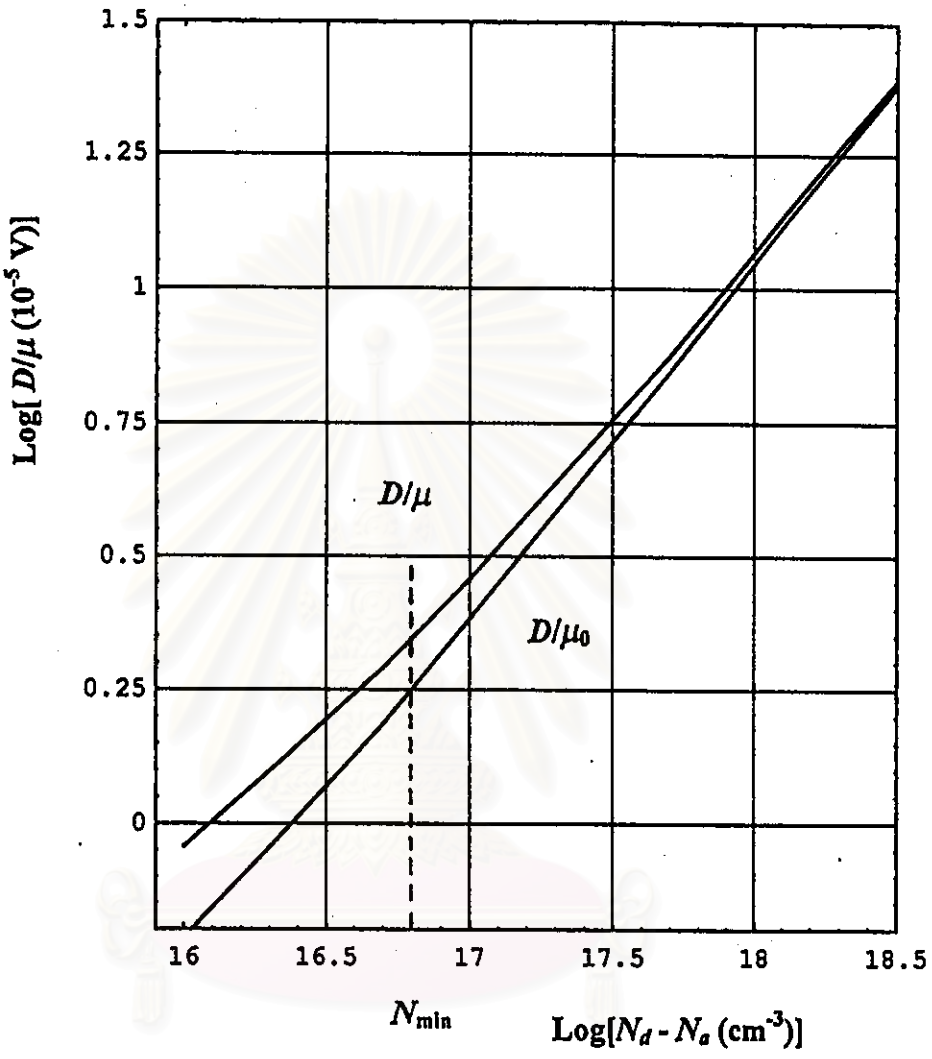

Figure 4 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.0$ and temperature $T = 10$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

N_{min} : minimum net carrier concentration for D/μ

$N_d - N_a$ (cm^{-3})	Q ($x10^6\ cm^{-1}$)	$\xi_Q^{1/2}$ (meV)	$E_f - E_C$ (meV)	D/μ ($x10^{-5}V$)	D/μ_0 ($x10^{-5}V$)	%diff
$1.000x10^{17}$	1.088	8.106	4.491	4.131	3.396	-17.8
$1.585x10^{17}$	1.251	9.515	9.515	4.519	4.066	-10.0
$2.000x10^{17}$	1.336	10.35	12.47	4.912	4.532	-7.74
$3.000x10^{17}$	1.485	12.02	18.51	5.904	5.530	-6.34
$4.000x10^{17}$	1.591	13.41	23.68	6.867	6.417	-6.55
$5.000x10^{17}$	1.674	14.61	28.31	7.782	7.307	-6.11
$6.000x10^{17}$	1.742	15.69	32.58	8.653	8.176	-5.51
$1.000x10^{18}$	1.935	19.22	47.43	11.80	11.33	-4.00
$5.000x10^{18}$	2.591	37.14	144.3	33.26	32.72	-1.80
$1.000x10^{19}$	2.916	49.53	230.5	52.49	51.89	-1.15
$5.000x10^{19}$	3.828	96.95	229.1	152.4	151.6	-0.51
$1.000x10^{20}$	4.300	127.3	1065	241.6	240.7	-0.36
$5.000x10^{20}$	5.632	251.9	3162	704.9	703.8	-0.16
$1.000x10^{21}$	6.322	336.2	5022	1118	1117	-0.11
$5.000x10^{21}$	8.244	658.5	$1.469x10^4$	3268	3267	-0.05

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Table 2 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.0$ and temperature $T = 77K$

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

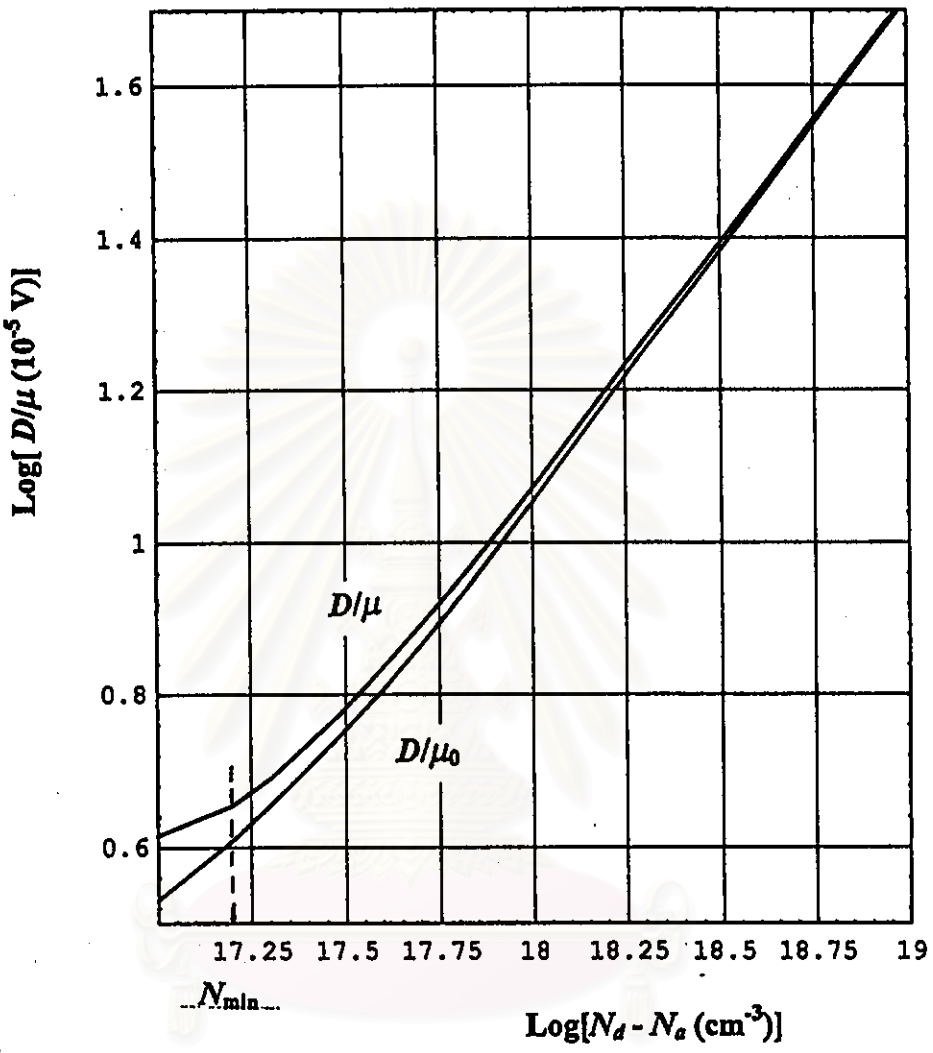

Figure 5 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.0$ and temperature $T = 77$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

N_{min} : minimum net carrier concentration for D/μ

N_d - N_a (cm^{-3})	Q (x10^6 cm^{-1})	$\xi_Q^{1/2}$ (meV)	E_f - E_C (meV)	D/μ (x10^{-5}V)	D/μ_0 (x10^{-5}V)	%diff
6.784x10^{17}	1.514	17.90	17.90	14.10	12.70	-9.90
8.000x10^{17}	1.599	18.91	24.31	13.99	13.41	-4.13
1.000x10^{18}	1.716	20.41	33.61	14.51	14.57	0.45
2.000x10^{18}	2.079	26.22	81.36	19.52	20.09	2.91
3.000x10^{18}	2.288	30.62	95.91	24.62	24.66	0.14
4.000x10^{18}	2.435	34.26	119.2	29.35	29.16	-0.65
5.000x10^{18}	2.548	37.45	140.3	33.76	33.50	-0.77
6.000x10^{18}	2.640	40.30	159.8	37.92	37.62	-0.78
7.000x10^{18}	2.718	42.91	178.1	41.87	41.54	-0.78
1.000x10^{19}	2.900	49.64	228.1	52.77	52.37	-0.75
5.000x10^{19}	3.825	96.68	678.0	152.5	151.8	-0.45
1.000x10^{20}	4.300	129.0	1078	241.6	240.8	-0.34
5.000x10^{20}	5.629	252.0	3162	704.9	703.8	-0.16
1.000x10^{21}	6.322	336.2	5021	1118	1117	-0.11
5.000x10^{21}	8.268	657.4	1.469x10^4	3268	3267	0.05

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Table 3 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.0$ and temperature $T = 300$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

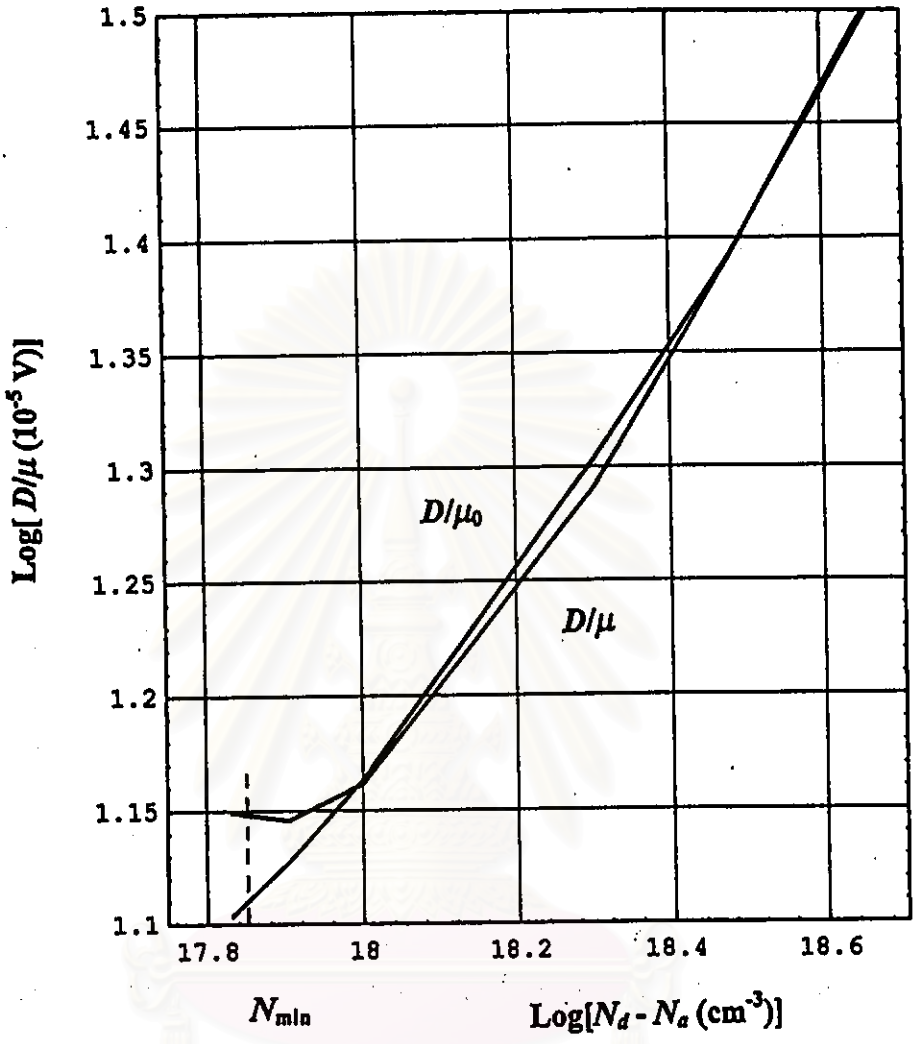

Figure 6 Dependence of the Einstein diffusion-mobility ratio on the net carrier

Figure 6 Dependence of the diffusivity-mobility ratio on the net carrier concentration

N_d-N_a for compensation ratio $N_a/N_d = 0.0$ and temperature $T = 300$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

N_{min} : minimum net carrier concentration for D/μ

N_d - N_a (cm^{-3})	Q ($x10^6$ cm^{-1})	$\xi_Q^{1/2}$ (meV)	E_f - E_C (meV)	D/μ ($x10^{-5}$V)	D/μ_0 ($x10^{-5}$V)	%diff
$1.000x10^{17}$	1.197	9.465	8.070	3.118	2.419	-22.4
$1.410x10^{17}$	1.293	10.82	10.82	3.771	3.037	-19.5
$5.000x10^{17}$	1.684	17.84	28.70	7.869	7.042	-10.5
$1.000x10^{18}$	1.928	23.59	47.16	12.02	11.17	-7.07
$5.000x10^{18}$	2.580	45.58	143.3	33.57	32.67	-2.68
$1.000x10^{19}$	2.909	60.71	229.3	52.81	51.85	-1.82
$5.000x10^{19}$	3.823	118.4	677.1	152.8	151.6	-0.79
$1.000x10^{20}$	4.297	158.0	1077	242.0	240.7	-0.54
$5.000x10^{20}$	5.625	308.8	3159	705.5	703.8	-0.24
$1.000x10^{21}$	6.320	412.0	5019	1119	1117	-0.18
$5.000x10^{21}$	8.265	805.4	$1.468x10^4$	3270	3267	-0.09

Table 4 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.2$ and temperature $T = 10$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

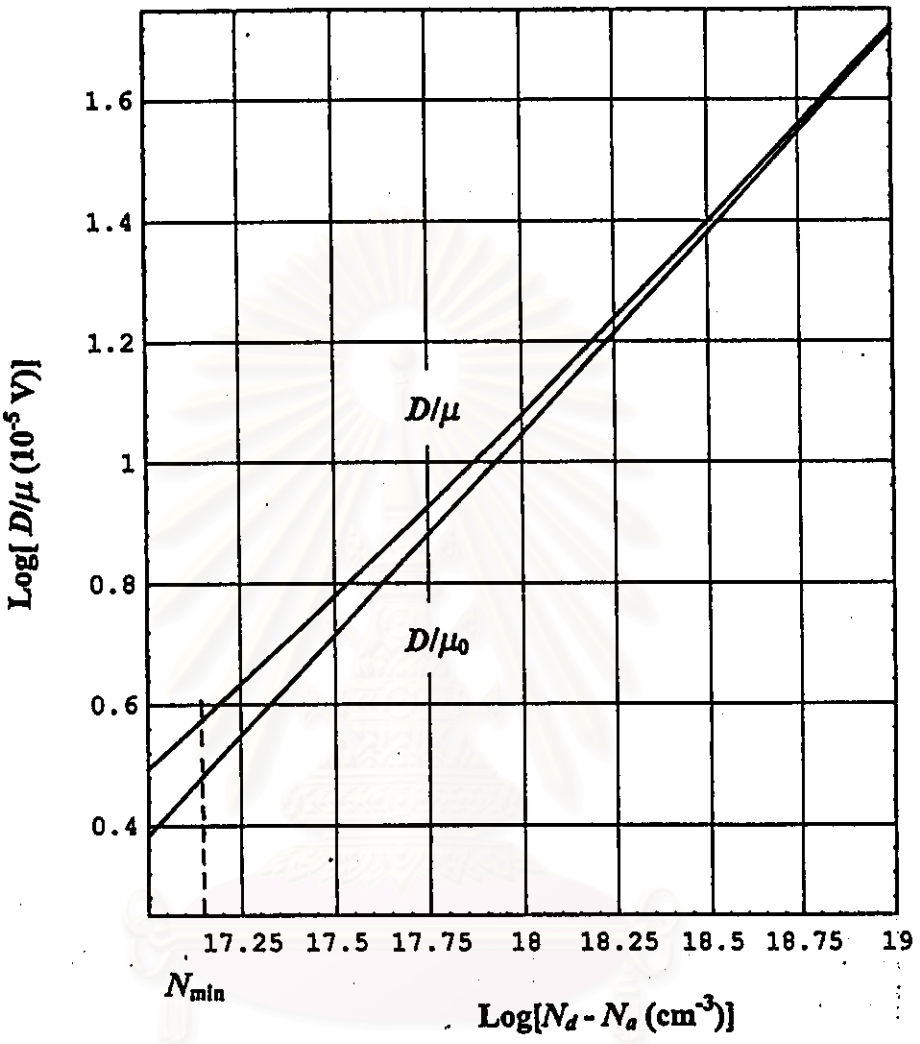

Figure 7 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.2$ and temperature $T = 10$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

N_{min} : minimum net carrier concentration for D/μ

$N_d - N_a$ (cm^{-3})	Q ($x10^6\ cm^{-1}$)	$\xi_Q^{1/2}$ (meV)	$E_f - E_C$ (meV)	D/μ ($x10^{-5}V$)	D/μ_0 ($x10^{-5}V$)	%diff
$1.000x10^{17}$	1.064	10.04	3.412	4.405	3.396	-22.9
$2.364x10^{17}$	1.365	13.62	13.62	5.632	4.920	-12.6
$5.000x10^{17}$	1.641	18.07	27.09	8.157	7.307	-10.4
$1.000x10^{18}$	1.906	23.72	46.21	12.17	11.33	-6.90
$5.000x10^{18}$	2.577	45.62	143.0	33.60	32.72	-2.62
$1.000x10^{19}$	2.909	60.70	229.1	52.83	51.89	-1.78
$5.000x10^{19}$	3.823	118.5	677.0	152.8	151.6	-0.79
$1.000x10^{20}$	4.296	158.0	1077	242.0	240.7	-0.54
$5.000x10^{20}$	5.627	308.7	3159	705.5	703.8	-0.24
$1.000x10^{21}$	6.317	412.0	5019	1119	1117	-0.18
$5.000x10^{21}$	8.266	805.5	$1.469x10^4$	3269	3267	-0.06

Table 5 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.2$ and temperature $T = 77K$

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

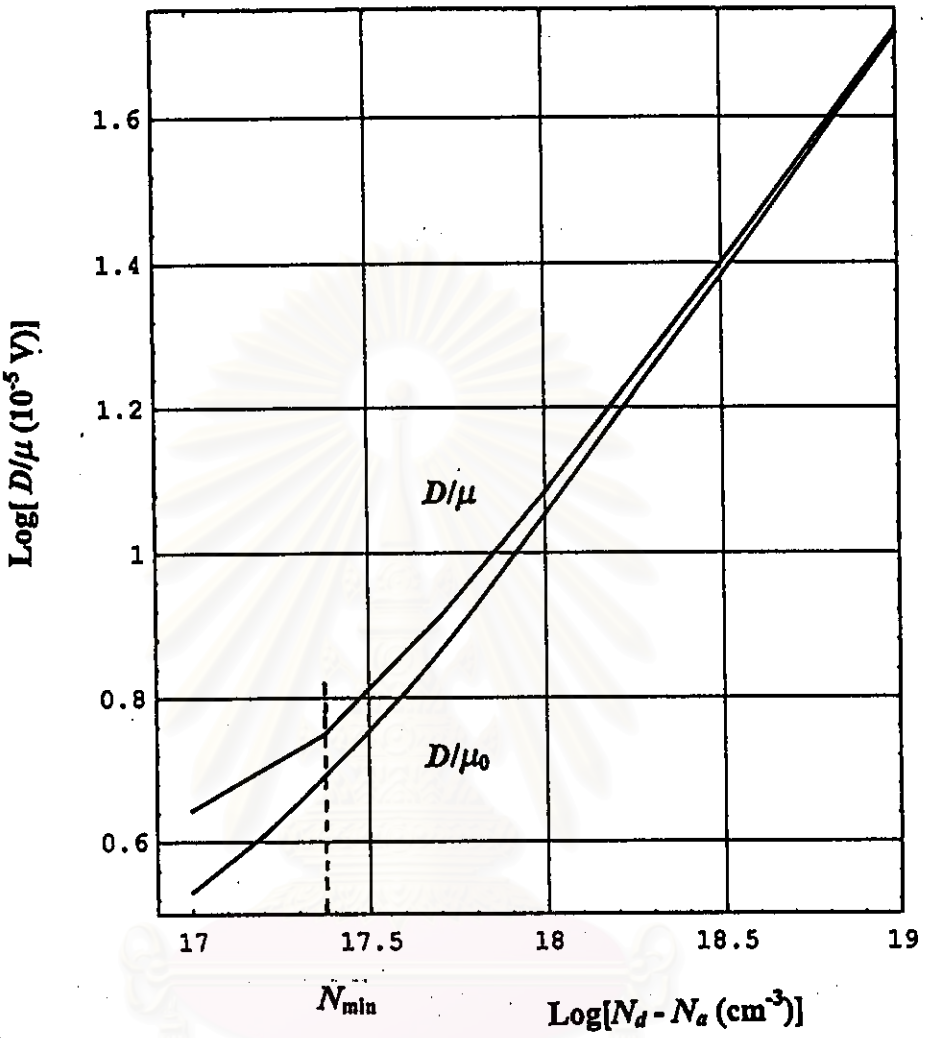

Figure 8 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.2$ and temperature $T = 77$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

N_{min} : minimum net carrier concentration for D/μ

N_d - N_a (cm^{-3})	Q ($x10^6\ cm^{-1}$)	$\xi_Q^{1/2}$ (meV)	E_f - E_C (meV)	D/μ ($x10^{-5}V$)	D/μ_0 ($x10^{-5}V$)	%diff
$8.111x10^{17}$	1.591	23.38	23.38	14.75	13.48	-8.61
$1.000x10^{18}$	1.699	25.13	32.10	15.23	14.57	-4.33
$5.000x10^{18}$	2.531	46.04	138.9	34.15	33.50	-1.90
$1.000x10^{19}$	2.889	60.94	226.7	53.13	52.37	-1.43
$5.000x10^{19}$	3.823	118.4	676.3	152.9	151.8	-0.72
$1.000x10^{20}$	4.295	158.0	1077	242.1	240.8	-0.54
$5.000x10^{20}$	5.630	308.5	3159	705.5	703.8	-0.24
$1.000x10^{21}$	6.319	411.9	5019	1119	1117	-0.18
$5.000x10^{21}$	8.267	805.4	$1.469x10^4$	3269	3267	-0.06

Table 6 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.2$ and temperature $T = 300K$

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

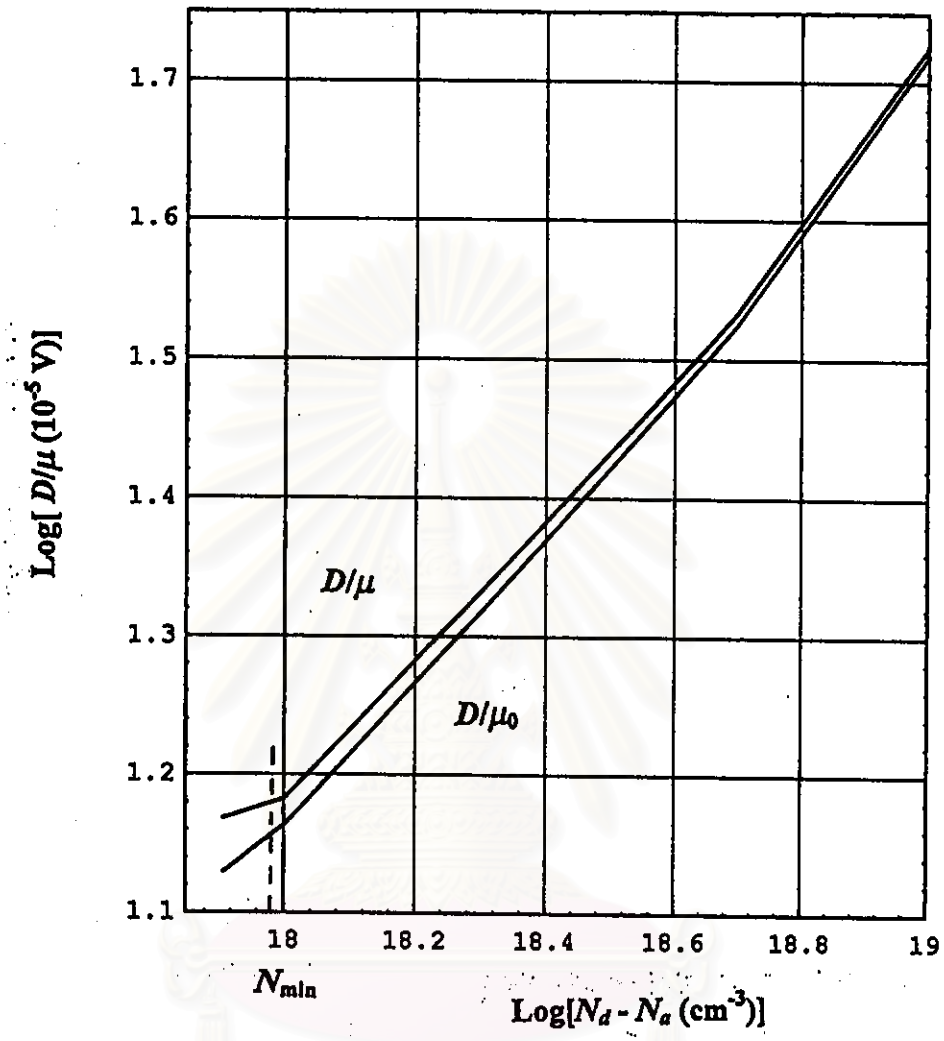

Figure 9 Dependence of the diffusivity-mobility ratio on the net carrier concentration N_d-N_a for compensation ratio $N_a/N_d = 0.2$ and temperature $T = 300$K

D/μ : The diffusivity-mobility ratio for n-type heavily doped semiconductors

D/μ_0 : The empirical diffusivity-mobility ratio

N_{min} : minimum net carrier concentration for D/μ

Table 4, 5, 6 and Figure 7, 8, 9 show the diffusivity-mobility ratio obtained for compensation ratio of N_a/N_d = 0.2 . Compensation lowers the diffusivity-mobility ratio and increase its dependence on the band tail density of states. However, in the region where $\xi_Q^{1/2} \leq E_f - E_C$ there is still little difference between the diffusivity-mobility obtained using the diffusivity-mobility for n-type heavily doped semiconductors (4.68) and the empirical diffusivity-mobility. The minimum values of net carrier concentration for which $\xi_Q^{1/2} \leq E_f - E_C$ are listed in Table 7.

Compensation ratio : N_a / N_d	Temperature : T (K)	N_{min} (cm^{-3})
0.0	10	6.471×10^{16}
	77	1.585×10^{17}
	300	6.784×10^{17}
0.2	10	1.410×10^{17}
	77	2.364×10^{17}
	300	8.111×10^{17}

Table 7 The minimum net carrier concentration, $N_{min} = (N_d - N_a)_{min}$, at which $\xi_Q^{1/2} \leq E_f - E_C$